(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 211 073 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
05.06.2002 Bulletin 2002/23

(51) Int Cl.7: B41J 2/05

(21) Application number: 00204247.1

(22) Date of filing: 29.11.2000

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(71) Applicant: Océ-Technologies B.V.
5914 CC Venlo (NL)

(72) Inventor: The designation of the inventor has not yet been filed

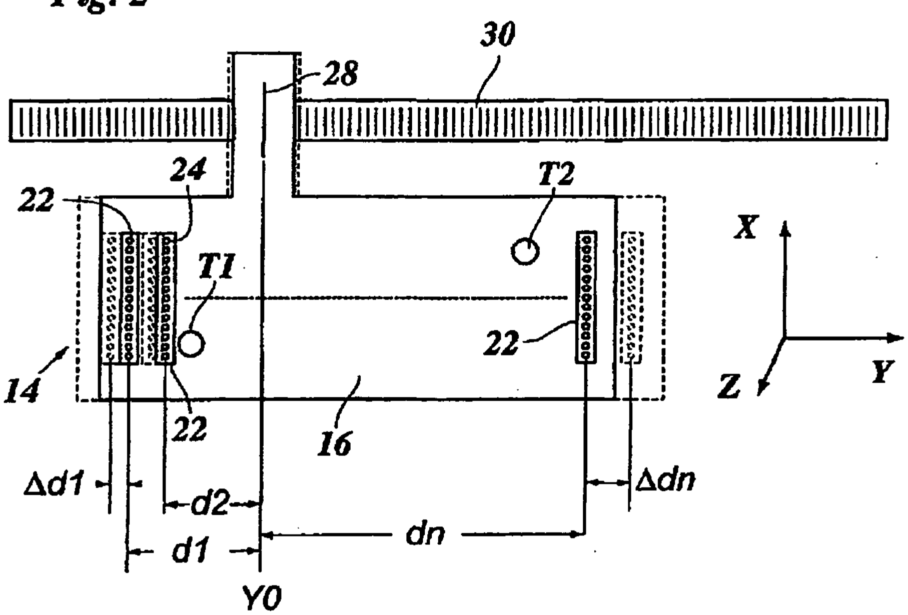
(74) Representative:
Rongen, Josephus Wilhelmus et al
Océ-Technologies B.V.,
Corporate Patents,
P.O. Box 101
5900 MA Venlo (NL)

(54) Ink jet printer and method controlling the same

(57) Method of controlling an ink jet printer comprising a printhead (14) movable relative to a recording medium in a main scanning direction (Y) and having a plurality of nozzles (24) spaced apart from each other in said main scanning direction and being energized at controlled timings for expelling ink droplets onto the recording medium, the method being characterized by the steps of:

- measuring at least one parameter, e. g. a temperature, that is correlated to the thermal expansion of the printhead (14),
- determining, for each of the nozzles (24), a thermally induced positional offset (Δd1 ... Δdn) in the main scanning direction on the basis of said parameter, and
- compensating the offsets of the individual nozzles by controlling the timings at which the nozzles are energized.

Fig. 2



EP 1 211 073 A1

Description

[0001] The invention relates generally to ink jet printing and more particularly to ink jet colour printing.

[0002] A typical ink jet colour printer has a printhead which is movable back and forth relative to a recording medium, e.g. a sheet of paper, in a main scanning direction. A plurality of nozzle arrays, at least one for each colour, are mounted on the printhead side-by-side in the main scanning direction. Each nozzle array has a plurality of nozzles arranged in one or more rows which extend in a sub-scanning direction in which the recording sheet is fed past the printhead, i.e. a direction orthogonal to the main scanning direction. In order to print an image on the recording sheet, ink droplets are expelled from the various nozzles, so that dots (pixels) are formed on the recording sheet. The positions of the dots formed on the recording sheet depend on the mechanical structure of the printhead. Further, the position in the main scanning direction depends on the timings at which the nozzles are energized during the continuous movement of the printhead, whereas the positions in the sub-scanning direction depend on the feed distance over which the recording sheet is fed after each scan pass of the printhead.

[0003] In order to obtain an artifact-free printed image of high quality, it is necessary that the dots are formed on the recording sheet with high positional accuracy. This is particular the case in a colour printer, because coloured seams would be visible in the printed image if the positions of the dots of different colours, which are formed by different nozzle arrays, were not adjusted correctly. In addition, even in a mono-colour printer, positional deviations of the dots in the sub-scanning direction would result in the occurrence thin lines with reduced or increased image density which separate the image areas that are formed during subsequent scan passes of the printhead.

[0004] In a so-called bubble-jet printer, the ink droplets are formed by heating the liquid ink, so that part of the ink is evaporated abruptly and creates a pressure which causes an ink droplet to be expelled from the nozzle. In a so-called hot melt ink jet printer, the ink is solid at room temperature and has to be heated above its melting point when the printer is operating. In this type of printer, the pressure for expelling the ink droplets is typically created by means of piezoelectric actuators. In any case, the printhead will be subject to temperature changes, and these temperature changes will influence the operating conditions of the printhead.

[0005] US-A-5 864 349 discloses an ink jet printer in which a temperature sensor is mounted on the printhead for monitoring the operating conditions of the printhead. US-A-4 544 931 and US-A-5 477 245 disclose ink jet printers in which the signal of a temperature sensor mounted on the printhead is used for controlling a frequency or pulse width of pulses with which the nozzles of the printhead are energized. JP-A-60 222 258 discloses an ink jet printer in which a print skew detector is mounted outside of the margin of the recording sheet, and the printhead is controlled to print dots on this detector during both the forward and the return scan pass of the printhead. By comparing the positions of the dots formed in the forward and return scan passes, the detector monitores the effect of a skew of the ink droplets which is caused by the movement of the printhead. When, due to temperature and moisture, any change in the conditions of the nozzles and the printhead carriage leads to a positional deviation of the dots formed in the forward and return strokes of the printhead, the detector will indicate these deviations and will cause the control system of the printer to perform an appropriate correction.

[0006] It is an object of the present invention to reduce the influence of the temperature of the printhead on the positional accuracy of dot formation without any need for complex detection systems.

[0007] According to the invention this object is achieved by a method of controlling an ink jet printer and by an ink jet printer as indicated in the independent claims.

[0008] The invention is based on the consideration that the influence of the temperature of the printhead on the positions where the dots are formed on the recording medium is mainly due to thermal expansion of the printhead. According to the general concept of the invention, at least one temperature sensor on the printhead is used for monitoring the temperature of the printhead or the temperature distribution within the printhead, so as to predict the effect of thermal expansion of the printhead on the nozzle positions on the basis of the known thermal expansion behavior of the printhead. Then, the predicted thermally induced positional offsets of the nozzles are compensated for by an appropriate control of the printer. Thus, it is sufficient to provide one or more temperature sensors for making the printer more robust against temperature changes of the printhead and for improving the positional accuracy in the dot formation.

[0009] In general, the printhead will undergo thermal expansion in all three dimensions and, as a result, the positions of the nozzles may be offset in the sub-scanning direction (X-direction), the main scanning direction (Y-direction) and also in the direction normal to the plane of the recording medium (Z-direction). Even the offset in the Z-direction may influence the positions of the dots, because it influences the distance between the nozzle and the recording medium and hence the time of flight of the ink droplets. Since, due to the movement of the printhead, the ink droplets have a velocity component in the main scanning direction (skew), an offset in the nozzle position in the Z-direction will lead to an offset in the dot position in the Y-direction. As the printhead moves in Y-direction, the deviations of the dot position in this Y-direction caused by nozzle offsets in the Y- and Z-directions can be compensated for by appropriately correcting the timings at which the nozzles are ener-

gized.

[0010] Offsets of the nozzle positions in the X-direction can be compensated for by appropriately correcting the feed distance of the recording medium. More specifically, when a nozzle array has a row of nozzles extending in the X-direction, the feed distance of the recording sheet between two subsequent scan passes of the printhead must be equal to the distance between the first and the last nozzle of the row plus the distance between two immediately adjacent nozzles of the row. Since these distances, especially the comparatively large distance between the first and the last nozzle, may vary in response to temperature changes, the feed distance of the recording sheet should be adapted accordingly.

[0011] In addition, depending on the structure of the printhead, thermal expansion of the mounting structure of the printhead may also cause a shift of the nozzle array, as a whole, in the X-direction. As long as the temperature is essentially constant over the time which is needed for printing one page, this shift will only lead to a minor shift of the printed image as a whole on the recording sheet and may be neglected. If, however, substantial temperature changes may occur between two printing operations in immediately adjacent or overlapping image areas, then this total shift of the nozzle array should be compensated as well.

[0012] It will generally depend upon the structure of the printhead and its mounting structure and on the required level of accuracy whether the nozzle offsets in all three directions, X, Y and Z or only selected ones of these offsets need to be compensated for.

[0013] The term "temperature sensor", as used in the description given above, should be interpreted in a broad sense. More precisely, what actually needs to be measured is a parameter that is correlated to the thermal expansion of the printhead and thus permits to determine the thermally induced offsets of the nozzle positions. In many known temperature sensors, the principle of temperature measurement is itself based on the measurement of the thermal expansion of a medium whose thermal expansion coefficient is known. Thus, it is also possible according to the invention to measure the temperature-dependent distance between two predetermined points on the printhead and to take this distance as a parameter which implicitly indicates the temperature of the printhead and thereby permits to determine the thermally induced positional offsets of the various nozzles.

[0014] More specific optional features of the invention are indicated in the dependent claims.

[0015] In a preferred embodiment, a predetermined point on the printhead is taken as a reference position in the Y-direction, and the absolute position of this point is directly measured with a linear encoder. Then, the Y-positions of the various nozzles are given as temperature-dependent distances between the nozzles and the reference position.

[0016] To determine the positions of the nozzles in X- and Z-directions, the printhead may be mounted slidably on a guide rail which defines a fixed reference position in the X- and Z-directions, so that the X- and Z-coordinates of the nozzles can again be given by temperature-dependent distances to the rexpectiv reference positions.

[0017] If the temperature of the printhead as a whole can be assumed to be uniform and if the structure of the printhead which determines the thermal expansion behavior is made of only a single material, e.g. aluminum, the temperature may be measured with a single temperature sensor, and the temperature-dependent relative positions of the nozzles may be calculated from the known thermal expansion coefficient of this material. On the other hand, if the printhead is composed of different materials, then the different thermal expansion coefficients of these materials may be taken into account in the calculation. As an alternative, it is possible to measure the relative positions of the nozzles at different temperatures in advance and to store the results in a look-up table in the control system of the printer.

[0018] If it is expected that the temperature of the printhead will, in operation, be non-uniform, then it is possible to employ a plurality of the temperature sensors, so that the temperature distribution within the printhead can be determined with sufficient accuracy by interpolation techniques, and the local thermal expansions can be calculated on the basis of this temperature distribution.

[0019] Preferred embodiments of the invention will now be described in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic perspective view of an ink jet colour printer to which the invention is applicable;

Fig. 2 is a diagrammatic front view of a printhead for explaining the method according to the invention;

Fig. 3 is a diagrammatic front view of a printhead according to a modified embodiment; and

Fig. 4 is a schematic cross-sectional view of a printhead according to another embodiment.

[0020] As is shown in figure 1, an ink jet colour printer comprises a platen 10 on which a recording sheet 12 is advanced in a sub-scanning direction X. A printhead 14 is moved back and forth along the platen 10 in a main scanning direction Y and comprises a carriage 16 mounted on guide bares 18, 20 and carries a number of nozzle arrays 22, at least one for each colour, which are arranged in the main-scanning direction Y. Each nozzle array comprises a number of nozzles 24 which, in the example shown, are arranged on a single straight line extending in the sub-scanning direction X. The pitch of the nozzles 24, i.e. the vertical distance of neighbouring nozzles, corresponds to the height of the pixels to be

printed on the recording sheet 12. These pixels are printed by ejecting droplets of coloured ink from the nozzles 24 in a direction Z normal to the plane of the recording sheet 12 where it faces the printhead. As is well known in the art, the droplets may be generated by means of thermal actuators (bubble-jet) or by means of piezoelectric actuators, for example.

[0021] When the printhead 14 makes a forward scan pass in the +Y-direction, a number of image lines is printed simultaneously on the recording sheet 12. Then, the recording sheet 12 is advanced by a distance corresponding to the height of the nozzle arrays plus a single pitch, and another group of lines is printed during the return scan pass of the printhead 14.

[0022] The printhead 14 is connected to a control unit 26 which controls the actuators for the various nozzles 24 in accordance with the image information of the image to be printed. The control unit 26 also controls the platen 10 for feeding the recording sheet 12.

[0023] As is shown in figure 2, the carriage 16 of the printhead 14 has a reference mark 28 which defines a fixed reference position Y0 for the Y coordinates of the nozzles 24 of all nozzle arrays 22. The absolute position of the reference mark 28 in the printer is detected by means of a linear encoder 30.

[0024] The temperature of the carriage 16, which may be considered to be a plate or frame of aluminum, is measured in two positions by means of temperature sensors T1 and T2. The signals of these temperature sensors are transmitted to the control unit 26 and may be averaged in order to obtain the overall temperature of the printhead 14. As an alternative, the two temperature signals may be evaluated separately, one for each half of the carriage 16. At a given standard temperature, the nozzle positions of the nozzle arrays 22 relative to the reference position Y0 are given by the values d1, d2, ..., dn. When the temperature of the printhead is increased, the printhead, mainly the carriage 16, will undergo thermal expansion, as is indicated in broken lines in figure 2. As a result, the nozzles positions of each nozzle array 22 are shifted by a thermally induced offset Δd1, ..., Δdn. In the control unit 26, these offsets are calculated on the basis of the measured temperature and the known thermal expansion coefficient of aluminum. When these offsets are divided by the known scanning speed of the printhead 14 in Y-direction, one obtains, for each nozzle array 22, a correction time by which the timings for energizing the nozzles must be delayed or advanced in order to compensate for the thermal expansion of the printhead. As a result, ink dots of different colour, which are generated by the different nozzle arrays 22, may be superposed directly one upon the other, or, more generally, the positional relationship between the dots may be preserved, irrespective of any temperature changes of the printhead. If the offsets are larger than (integer times) the distance between two pixels on the recording sheet in the main scanning direction, then, in a preffered embodiment, the delay or advancement of the timings is carried out only to compensate that part of the offsets that is larger than this distance. The part of the offset that is exactly the same as (integer times) the distance between two pixels is in this embodiment carried out by displacing the printhead over this distance. This way, the actual timing delay or advancement is only used for compensating the small deviations in between the pixels, which is a further improvement of the method according to the invention.

[0025] Figure 3 illustrates an embodiment in which the printhead 14 is not provided with any temperature sensors but, instead, a second reference mark 32 is provided on the carriage 16. The position of the second reference mark 32 can also be measured by means of the linear encoding 30. At standard temperature, the distance between the reference marks 28 and 32 is D. Thermal expansion leads to a change of this distance by a value ΔD which can exactly be measured with the linear encoding. If desired, the temperature of the carriage 16 (which is assumed to be uniform in this case) can be calculated by dividing the ratio ΔD/D through the thermal expansion coefficient. However, the offsets Δd1 ... Δdi ... Δdn for each nozzle array 22 can dirictly be obtained according to the formula:

$$\Delta di = di \,.\, \Delta D/D$$

[0026] While only the effect of thermal expansion in the main scanning direction Y has been considered in the embodiments discussed above, figure 4 exemplifies the effects of thermal expansions in the directions X and Z. In the embodiment shown in figure 4, a printhead 34 has a carriage 36 which is slidably mounted on a single guide rail 38 which extends in the main scanning direction Y. The central axis of the guide rail 38 defines a fixed referenced position X0 for the sub-scanning direction X and a fixed reference position Z0 for the Z-direction in which the ink droplets are expelled.

[0027] The carriage 36 has two support bars 40, 42, and the nozzle arrays 22 (only one of which is visible in figure 4) are held between these support bars by means of mounting frames 44. Each mounting frame is held on the support bars 40, 42 with positioning pins 46, 48 which engage into positioning holes of the support bars 40, 42, respectively.

[0028] It is assumed here that the material of the nozzle arrays 22 is different from that of the carriage 36, so that these components may undergo differential thermal expansion. This is why only the positioning pin 46 is fitted into the corresponding positioning hole without play, whereas the positioning pin 48 is received in an elongated positioning hole of the support bar 42 so that it has a little play in X-direction. The nozzles of the nozzle arrays 22 are not visible in figure 4, but the positions of the first nozzle a and the last nozzle b of the row of nozzles are indicated in the drawing. The temperatures of the nozzle arrays 22 are monitored by means of tem-

perature sensors T3. A separate temperature sensor may be provided for each nozzle array, and the measured temperatures may be averaged. Another temperature sensor T1 detects the temperature of the carriage 36.

[0029] The free end of the carriage 36 may be guided by an auxiliary guide rail 50, which, however, does not restrain the thermal expansion of the carriage.

[0030] The recording sheet 12 is in this embodiment passed over two feed rollers 52 so that the printing region is held in parallel with the front face of the nozzle arrays 22. This assures that the ink droplets expelled from the various nozzles all have to travel the same distance until they impinge on the recording sheet 12.

[0031] The effect of thermal expansion of the carriage 36 and the nozzle arrays 22 is again indicated by broken lines. It can be seen that the thermal expansion of the carriage 36, mainly of the support bars 40, 42, in Z-direction leads to an offset Δz in the distance between the front face of the nozzle arrays 22 and the recording sheet 12. Dividing this offset Δz by the known velocity of the ink droplets in Z-direction gives a change Δt in the time of flight of the ink droplets. Since the printhead 34 is moved in the main scanning direction Y when the ink droplets are ejected, the ink droplets also have a velocity component in the Y-direction, and this would give rise to a deviation in the Y-position of the dots formed on the recording sheet. In order to compensate for this effect, the energizing timings for the nozzles must be delayed by the time Δt. The offset Δz can be calculated from the distance between the nozzles and the reference position Z_0 at standard temperature, the temperature measured by the temperature sensor T1 and the known thermal expansion coefficient of the carriage 36.

[0032] The thermal expansion of the carriage and the nozzle arrays in the sub-scanning direction X influences the feed distance F over which the recording sheet 12 must be fed between two subsequent scan passes of the printhead.

[0033] At standard temperature, the height of the nozzle array 22, i.e. the distance between the first nozzle a and the last nozzle b is H0. If it is assumed that the nozzle array has N nozzles arranged in a single row and the pitch of the nozzles, i.e. the distance between two adjacent nozzles is p, then: H0 = (N-1) p. Thus, in order to obtain equidistant lines of printed pixels on the recording sheet 12, the sheet must be fed in X-direction over a feed distance F = N.p = N H0/(N-1). However, if the nozzle array 22 has undergone thermal expansion and the distance between the nozzles a and b has changed to H1 (offset = H1 - H0), then the feed distance is F = N H1/(N-1). H1 can be calculated from the height H0 at standard temperature, the temperature measured with the temperature sensor T3 and the thermal expansion coefficient of the nozzle array 22.

[0034] In addition, as is shown in figure 4, thermal expansion of the carriage 36 in X-direction gives rise to an offset Δa in the position of the first nozzle a in X-direction. This offset may be ignored as long as it is constant over the printing time. However, if the temperature of the carriage 36 and hence the offset Δa are not constant, then the feed distance F should also be corrected by the difference between the current offset •a and the previous offset that had been obtained at the beginning of the last scan pass. In general, a correction of this type will only be necessary if the printing process is interrupted for a considerable time during which the temperature of the carriage may change or if, e.g. in a plotting mode of the printer, the recording sheet 12 is fed forward and rearward in order to print multiple images that are superposed one upon the other. The offset Δa can be calculated from the known distance between the nozzle a and the reference position X0 at standard temperature, the temperature measured with the temperature sensor T1 and the thermal expansion coefficient of the carriage 36.

In the embodiment shown in figure 4, the offsets of the nozzle arrays 22 in the main scanning direction Y may be compensated in the same manner as has been described in conjunction with figures 2 and 3.

Claims

1. Method of controlling an ink jet printer comprising a printhead (14; 34) movable relative to a recording medium (12) in a main scanning direction (Y) and having a plurality of nozzles (24) spaced apart from each other in said main scanning direction and being energized at controlled timings for expelling ink droplets onto the recording medium, the method being **characterized by** the steps of:

   - measuring at least one parameter (ΔD) that is correlated to the thermal expansion of the printhead (14; 34),
   - determining, for each of the nozzles (24), a thermally induced positional offset ($\Delta d1 \ldots \Delta dn$) in the main scanning direction on the basis of said at least one parameter, and
   - compensating the offsets of the individual nozzles by controlling the timings at which the nozzles are energized.

2. Method according to the preamble of claim 1 or to claim 1, **characterized by** the steps of:

   - measuring at least one parameter (ΔD) that is correlated to the thermal expansion of the printhead,
   - determining, on the basis of said at least one parameter, a thermally induced positional offset (Δz) of the nozzles in a direction (Z) orthogonal to the plane of the recording medium (12), which offset causes variations in the time of flight of the ink droplets from the nozzles to the

recording medium, and

- compensating said variations by controlling the timings at which the nozzles are energized.

3. Method, in particular according to claim 1 or 2, for controlling an ink jet printer comprising a printhead (34) movable relative to a recording medium (12) in a main scanning direction (Y), and a feed system (52) for moving the recording medium relative to the printhead in a sub-scanning direction (X) orthogonal to said main scanning direction, such that the recording medium is fed over a controlled feed distance (F) after each scan pass of the printhead (34) in the main scanning direction, wherein the printhead (34) has a plurality of nozzles (a, b) spaced apart from each other in said sub-scanning direction (X), the method being **characterized by** the steps of:

- measuring at least one parameter that is correlated to the thermal expansion of the printhead (34),
- determining a thermally induced positional offset (Da; H1-H0) of the nozzles in the sub-scanning direction (X) on the basis of said at least one parameter, and
- compensating this offset by controlling the feed distance (F).

4. Method according to any of the preceding claims, wherein the control of the energizing timings for the nozzles is based on a measurement of a position, in the main scanning direction (Y), of a fixed point (28) on the printhead (14), said fixed point (28) defining a reference position (Y0), and wherein the offsets (Δd1 ... Δdn) in the main scanning direction are determined as changes in the distances (d1 ... dn) of the nozzles (24) from said reference position (Y0).

5. Method according to any of the preceding claims, wherein said at least one parameter is a temperature measured at at least one point of the printhead (14; 34).

6. Method according to claim 5, wherein the temperatures are measured at different positions on the printhead (14; 34), and the step of determining the thermally induced positional offset comprises a step of deriving a temperature distribution of the printhead from the measured temperatures.

7. Method according to any of the preceding claims, wherein said at least one parameter is a temperature-dependent distance (ΔD) between two fixed points (28, 32) of the printhead.

8. Ink jet printer having a control unit (26) in which a method according to one of the claims 1 to 7 is implemented.

9. Ink jet printer according to claim 8, comprising a printhead (14; 34) which has a carriage (16; 36) and a plurality of nozzle arrays (22) mounted on said carriage side-by-side in a main scanning direction (Y), each nozzle array having at least one row of nozzles (24) extending in the sub-scanning direction (X).

10. Printer according to claim 9, wherein said carriage (36) is guided on a guide rail (38) which defines fixed reference positions (X0, Z0) in the sub-scanning direction (X) and the direction normal to the plane of the recording medium (12).

Fig. 1

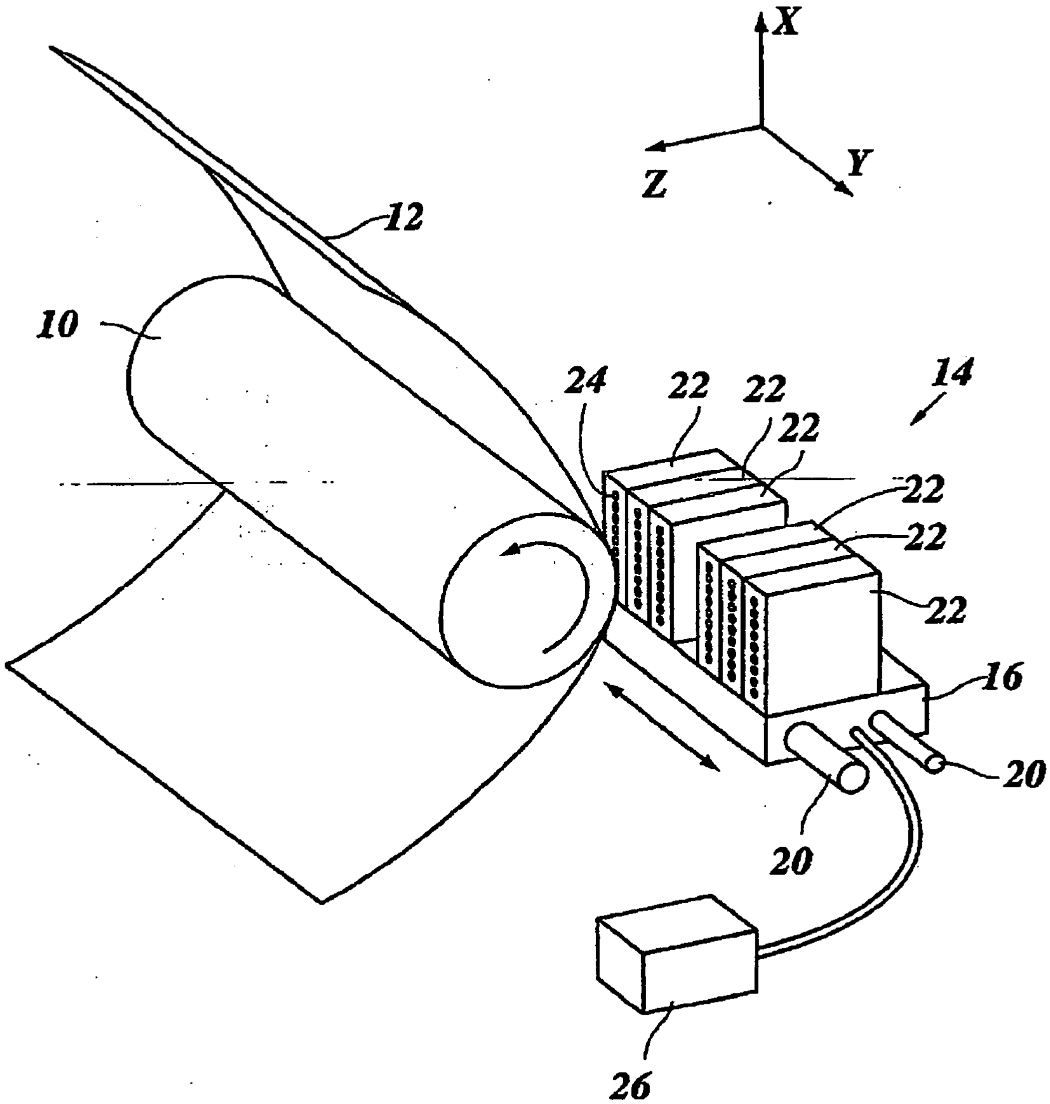


Fig. 2

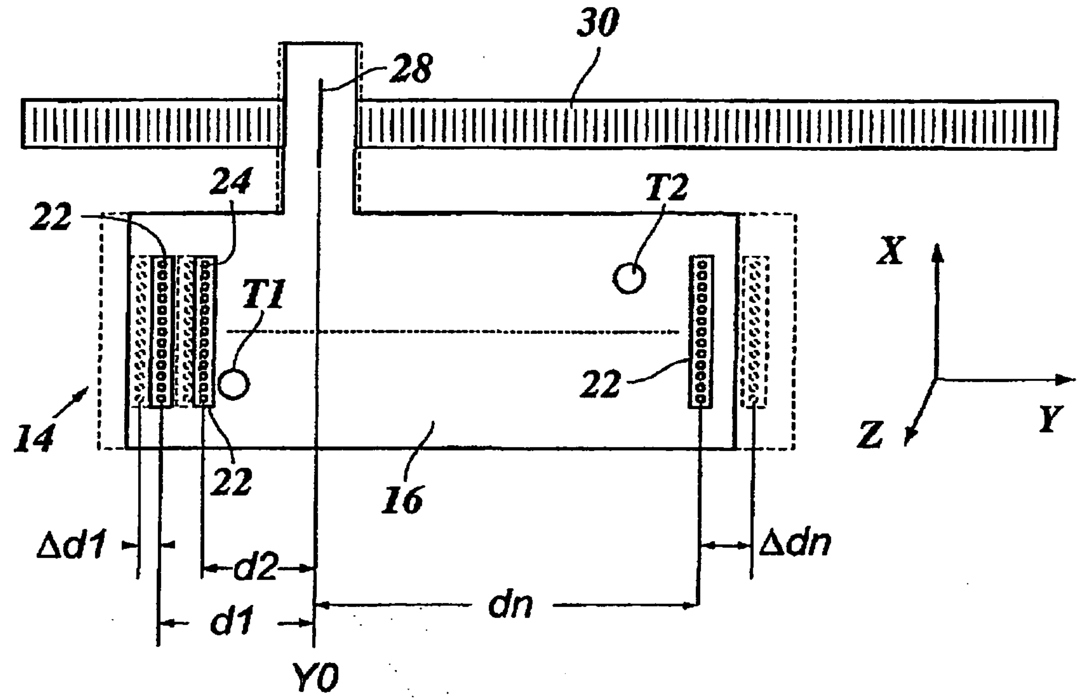

30
28
24
22
T2
X
T1
22
14
22
Z
Y
16
Δd1
Δdn
d2
dn
d1
Y0

Fig. 3

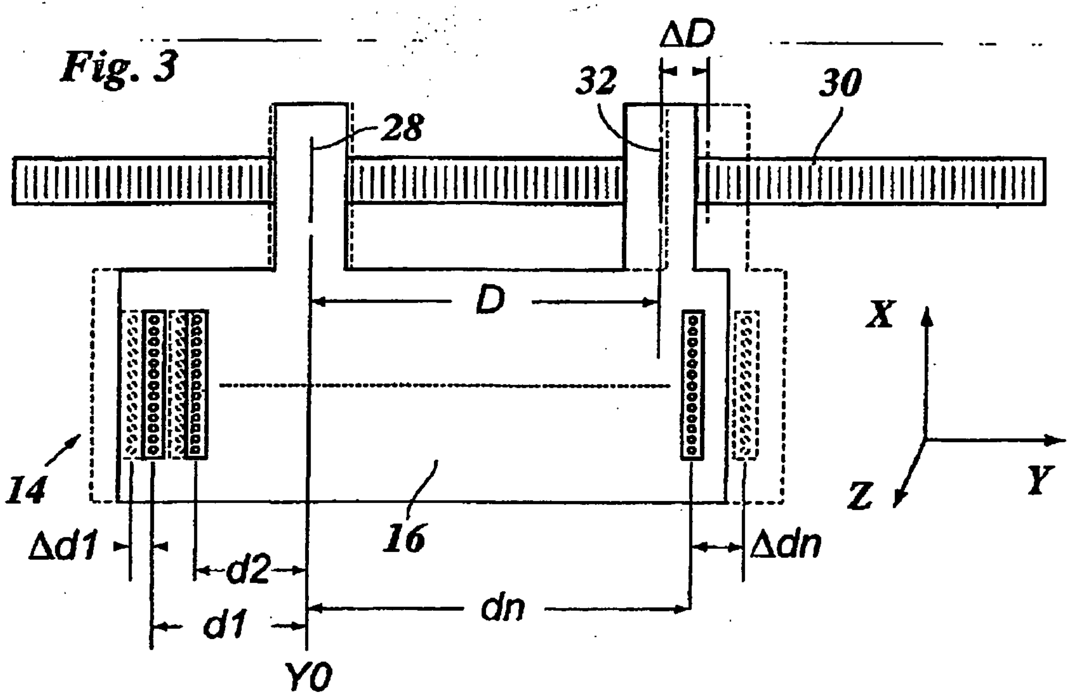

ΔD
32
30
28
D
X
14
Z
Y
Δd1
16
Δdn
d2
dn
d1
Y0

Fig. 4